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Background: Rubbing moist skin results in higher frictional forces than rubbing very dry skin. As friction increases, the probability of activity-related blisters also increases. Therefore reducing Moisture may reduce blister incidence during physical activity.

Objective: We examined whether an antiperspirant can reduce foot blisters during hiking.

Methods: In a double-blind study, cadets attending the US Military Academy were separated into two groups that used either an antiperspirant (20% aluminum chloride hexahydrate in anhydrous ethyl alcohol) or placebo (anhydrous ethyl alcohol) preparation. Cadets were told to apply preparations to their feet for 5 consecutive nights. On day 6, cadets completed a 21-km hike, and their feet were examined for blisters before and after.

Results: Because of dropouts, the final sample size was 667 cadets with 328 in the antiperspirant group and 339 in the placebo group. There was a high rate of noncompliance with the treatment schedule: Cadets used the preparations from 0 to 5 nights before the hike. For cadets using the preparations at least 3 nights before the hike (n=269), the incidence of foot blisters was 21% for antiperspirant group and 48% for the placebo group ($P < 0.01$). However, reports of skin irritation were 57% for the antiperspirant group and 6% for the placebo group ($P < 0.01$).

Conclusion: A 20% solution of aluminum chloride exaggerate in anhydrous ethyl alcohol may be effective in reducing foot blisters during hiking; however, the side effect of skin irritation should be considered and preventive measures studied to reduce this irritation.

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# Influence of an antiperspirant on foot blister incidence during cross-country hiking

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***Background:*** Rubbing moist skin results in higher frictional forces than rubbing very dry skin. As friction increases, the probability of activity-related blisters also increases. Therefore reducing moisture may reduce blister incidence during physical activity.
***Objective:*** We examined whether an antiperspirant can reduce foot blisters during hiking.
***Methods:*** In a double-blind study, cadets attending the US Military Academy were separated into two groups that used either an antiperspirant (20% aluminum chloride hexahydrate in anhydrous ethyl alcohol) or placebo (anhydrous ethyl alcohol) preparation. Cadets were told to apply preparations to their feet for 5 consecutive nights. On day 6, cadets completed a 21-km hike, and their feet were examined for blisters before and after.
***Results:*** Because of dropouts, the final sample size was 667 cadets with 328 in the antiperspirant group and 339 in the placebo group. There was a high rate of noncompliance with the treatment schedule: Cadets used the preparations from 0 to 5 nights before the hike. For cadets using the preparations at least 3 nights before the hike ($n = 269$), the incidence of foot blisters was 21% for the antiperspirant group and 48% for the placebo group ($P < 0.01$). However, reports of skin irritation were 57% for the antiperspirant group and 6% for the placebo group ($P < 0.01$).
***Conclusion:*** A 20% solution of aluminum chloride hexahydrate in anhydrous ethyl alcohol may be effective in reducing foot blisters during hiking; however, the side effect of skin irritation should be considered and preventive measures studied to reduce this irritation.
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Foot blisters are one of the most common injuries an active person can experience.[1,2] They are usually minor and usually require only simple first aid and a short period of limited activity.[3] However, blisters may also lead to cellulitis or sepsis.[1,4] Blisters have been a challenge to military forces throughout history[5,6] because they can reduce locomotion, impair concentration, and affect the soldier's ability to respond to emergencies.

Frictional shearing forces appear to be the cause of most activity-related blisters.[1,7,8] Rubbing moist skin produces higher frictional forces than rubbing very dry or very wet skin[1,9-12]; this suggests that reducing sweating might reduce friction and consequently reduce blisters. Case studies have demonstrated that topical antiperspirants reduced blistering events after exercise.[13-15] One double-blind, placebo-controlled, crossover study used the antiperspirant aluminum zirconium tetrachlorohydrex glycine in a proprietary emollient base and studied the incidence of foot blisters while subjects were walking in the heat for 4 hours. Investigators found no difference between experimental and placebo conditions; however, sweating was not

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reduced, and it was hypothesized that the emollient may have interfered with the antiperspirant action.[16]

The purpose of this investigation was to examine the effectiveness of an antiperspirant without emollients in reducing the incidence of foot blisters during prolonged cross-country hiking. Hiking was chosen because it often produces a high incidence of foot blisters.[5,17,18]

## METHODS

### Subjects

Subjects were 1130 new cadets (plebes) at the US Military Academy (USMA), West Point, New York. They volunteered after a briefing on the purposes and risks of the study and signing an informed consent statement. There were initially 1159 volunteers (96% of the freshman cadets), but 29 cadets reported a history of problems with antiperspirants or alcohol-based preparations and did not participate in the study.

### Experimental design and preparation formulas

A double-blind, placebo-controlled experimental design was used. Half the cadets received the placebo preparation and the other half an antiperspirant. The placebo was a specially denatured alcohol (SDA 40-2 anhydrous) consisting of 99.9% ethyl alcohol, 0.1% T-butyl alcohol, and 0.01% brucine sulfate. The antiperspirant was a 20% solution of aluminum chloride hexahydrate in the same anhydrous ethyl alcohol base (Drysol).[19,20] The compound may act as a chemical irritant, increasing keratinization of the sweat ducts and blocking the exit of sweat from these glands.[21,22]

### Procedures

Cadets completed a questionnaire that asked them about their previous hiking and military experience. Six days before the hike, cadets were instructed in a large group on how to apply the preparations to the foot. They were provided a plastic bottle labeled with their name, subject number, and application instructions. The preparation was to be applied for 5 consecutive nights at bedtime. It was emphasized that the entire foot was to be covered (up the ankle to the top of the boot line) and that the preparation should be applied to a completely dry foot. There were foam applicators on the bottle that allowed easy application of the liquid preparations.

The cadets' feet were examined on the evening before the hike for blisters, broken blisters, and blood blisters. The location of each blister was recorded on a specially designed data sheet. A blister was defined as an elevated, fluid-filled vesicle lighter in color than the surrounding tissue. A broken blister was defined as a lighter-colored, torn piece of skin under which part of the epidermis was exposed. A blood blister was defined as an elevated, fluid-filled vesicle darker in color than the surrounding tissue and presumably holding blood. These conditions were clearly distinguished from abrasions, callouses, bruises, and peeling skin in training and practice sessions before the study. During the pre-hike foot examination, cadets were verbally asked, "Did you experience any irritation as a result of using the preparation?" A "yes" or "no" response was recorded.

**Table I.** Temperature and humidity during the hike

| Time of day (Hour-military time) | Temperature (°C) | Relative humidity (%) |
|---|---|---|
| 0500 | 19 | - |
| 1010 | 25.1 | 81 |
| 1224 | 28.4 | 84 |

All cadets performed the 21-km hike on a single day in about 6.5 hours. Two previous hikes of 5 km and 13 km had been completed by the cadets in the 5 weeks before this hike. The cadets had worn their boots for these hikes and other daily activities so they were well broken in. For the 21-km hike, the total prescribed load (uniform, boots, and all equipment) had a mass of about 33 kg. The hike was predominantly uphill with slopes ranging from flat to nearly 55 degrees at one point. Temperatures and humidity during the hike were obtained from a meteorological station located at the USMA and are shown in Table I.

On completion of the hike, cadets removed their equipment and packs and were seated on a grassy knoll. They completed a short questionnaire that asked them how many nights they had applied the preparations, the type of socks worn on the hike, type of boots worn, and anything additional they had worn on their feet (e.g., moleskin, adhesive tape, etc.). The cadets then removed their boots and examiners inspected their feet for blisters using the same criteria as the pre-hike examination.

## RESULTS

Many cadets did not complete the study. Reasons included nonavailability for the pre-hike or post-hike examination (because of other military duties), medically excused, noncompletion of the hike, and resignation from the academy before the hike. The final sample size was 667 (59% of the volunteers) with 328 in the antiperspirant group and 339 in the placebo group. There was a high rate of noncompliance with the 5-day application schedule. The number of times the subjects

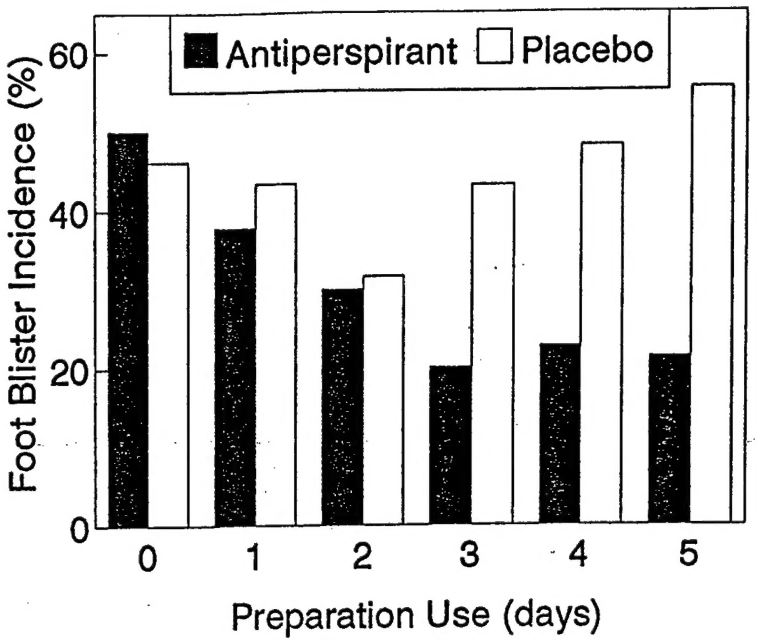


**Fig. 1.** Foot blister incidence in antiperspirant and placebo groups after 21-km hike.

**Table II.** Subjects by group and days of preparation use

| | Days of preparation use | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 |
| Antiperspirant | | | | | | |
| N* | 56 | 74 | 70 | 70 | 44 | 14 |
| Part of total (%)† | 17 | 23 | 21 | 21 | 13 | 4 |
| Placebo | | | | | | |
| N* | 65 | 76 | 57 | 51 | 52 | 38 |
| Part of total (%)† | 19 | 22 | 17 | 15 | 15 | 11 |

*Number of subjects.
†Part of total for group: Total $N = 328$ for antiperspirant group; total $N = 339$ for placebo group.

used the preparations ranged from 0 to 5 days. Table II shows the number of cadets in both groups by days of preparation use. Because of the high rate of noncompliance we subcategorized the two groups (antiperspirant and placebo) into days of preparation use. Pearson chi-square statistics were used to test the hypothesis of no difference between treatment groups and subgroups. Pre-hike blister data sheets were compared with post-hike sheets and only blisters that originated during the hike were considered in the data analysis.

Cadets in the antiperspirant group had a 32% incidence of foot blisters, whereas cadets in the placebo group had a 44% incidence ($P < 0.01$). Fig. 1 shows the foot blister incidence plotted by days of preparation use. The placebo and antiperspirant groups did not differ in subgroups using the preparations for 0 ($P = 0.67$), 1 ($P = 0.49$), or 2 ($P = 0.85$) days; however, there were significant differences between placebo and antiperspirant groups in subgroups using the preparations 3 ($P = 0.01$), 4 ($P = 0.01$), or 5 ($P = 0.03$) days. Overall incidence of blisters in subjects using the preparations 0 to 2 days was 39% in the antiperspirant group and 41% in the placebo group ($P = 0.62$); for subjects using the preparations 3 to 5 days, overall incidence of blisters was 21% in the antiperspirant group and 48% in the placebo group ($P < 0.01$).

In the antiperspirant group, 26% of cadets reported that their feet did not sweat during the

hike, compared with 12% in the placebo group ($P < 0.01$). Placebo and antiperspirant groups did not differ in subgroups using the preparations for 0 ($P = 0.67$), 2 ($P = 0.17$), or 5 days ($P = 0.13$); however, there were significant differences in groups using the preparations 1 ($P = 0.02$), 3 ($P < 0.01$), or 4 ($P = 0.01$) days. Overall, for cadets using the preparations for 0 to 2 days, 15% of those in the antiperspirant group and 9% of those in the placebo group reported that their feet did not sweat ($P = 0.07$); for cadets using the preparations 3 to 5 days, 45% of those in the antiperspirant group and 17% of those in the placebo group reported that their feet did not sweat ($P < 0.01$).

In all the days-of-use subgroups, subjects who used the antiperspirant reported significantly more irritation ($P < 0.01$) than those using the placebo. The overall incidence of self-reported irritation was 57% in the antiperspirant group and 6% in the placebo group.

It was possible that previous hiking or military experience, or socks or other materials or substances worn on the foot could have influenced blister incidence. To address this possibility, questionnaires were used to look for differences ($P < 0.10$) in the number of cadets in the antiperspirant and placebo groups in response to each of 15 questions. On only one question ("What type of boots did you wear?") was there a difference between the antiperspirant and placebo groups in terms of the number of subjects responding "yes" or "no" ($P < 0.01$). When the boots were fitted to each cadet on the second or third day at the academy (5 weeks before the 21-km hike), there were only two selections, the speed lace and lace-up types. Lace-up boots were more likely to be worn by cadets in the antiperspirant group. However, when subjects wearing lace-up boots were eliminated from the data analysis, the results were essentially unchanged; that is, for cadets using the preparations for 0 to 2 days, blister incidence was 42% in the antiperspirant group and 42% in the placebo group ($P = 0.92$); for cadets using the preparations 3 to 5 days, blister incidence was 17% in the antiperspirant group and 47% in the placebo group ($P < 0.01$).

## DISCUSSION

The present study suggests that a 20% solution of aluminum chloride hexahydrate in anhydrous ethyl alcohol can reduce the incidence of foot blisters during prolonged cross-country hiking if applied at least three times on 3 separate days before a hike. Compared with the placebo group, cadets using the antiperspirant at least 3 nights before the hike had a 56% lower incidence of blisters.

Because moisture increases friction,[1,8] and friction appears to be the cause of most foot blisters seen during physical activity,[7,18] we hypothesized that reducing sweating through the use of antiperspirants should reduce blister incidence. Of the cadets who used the preparations at least three times before the hike, many more of those in the antiperspirant group reported that their feet did not sweat, compared with the placebo group (45% vs 17%). These data lend support to the idea that sweat reduction was the mechanism for the reduction in blister incidence. Darrigrand et al.[20] applied a 24% aqueous solution of aluminum chlorohydrate and measured sock and boot weight before and after a 1-hour treadmill walk in the heat (32°C). They found a 55% reduction in total sweat accumulation with the antiperspirant. Foot-skin temperature was not different between control and antiperspirant groups, suggesting that local thermoregulation was not affected by the antiperspirant.

Our results differ from those of Reynolds et al.[16] who found that an antiperspirant (20% aqueous solution of aluminum zirconium tetrachlorohydrex glycine) with emollient did not reduce the incidence of foot blisters during 4 hours of walking on a treadmill. However, the emollient may have interfered with the antiperspirant action,[12] because the preparation did not reduce sweating as measured by weighing socks after the walk. Darrigrand et al.[20] also reported that a 24% solution of aluminum chlorohydrate resulted in no significant reduction in blister incidence in soldiers walking on a treadmill for 1 hour. However, when we reanalyzed their data we found that blisters were, in fact, reduced. All nonparametric tests for related samples (Friedman Test, Cochran's Q, and Kendall's W) showed an overall reduction in blister incidence when the placebo group was compared with the aluminum chlorohydrate group ($P < 0.01$ for all tests).

The verbal responses of subjects suggested that much more skin irritation occurred in the antiperspirant group. In consonance with our data, Darrigrand et al.[20] reported a 44% incidence of irritant dermatitis (7 of 16 subjects) in soldiers

using a 24% aqueous solution of aluminum chlorohydrate for 3 days. Reynolds et al.[16] reported no irritant dermatitis when an emollient was combined with aluminum zirconium tetrachlorohydrex glycine, but this compound did not reduce sweating or blister incidence.

Based on our data, it seems reasonable to suggest that a 20% solution of aluminum chloride hexahydrate in anhydrous ethyl alcohol can reduce the incidence of foot blisters if applied on at least 3 separate days before a long cross-country hike. However, the side effects of irritation must be considered and more fully characterized in future studies. There may be methods of reducing skin irritation while preserving the favorable antiperspirant property. These include using lower concentrations of aluminum chlorhydrate, changing the treatment schedule (eg, use every other or every third night), or combining the active ingredient (aluminum chloride hexahydrate) with a cortisone-based preparation. A common-sense approach is to discontinue use of the antiperspirant if irritation occurs.

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